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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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McCLELLEN CREEK BASIN
NORTHERN PACIFIC RESERVOIR DAM
EAST HELENA, MONTANA
MT-858

PREPARED FOR:

HONORABLE THOMAS L. JUDGE
GOVERNOR, STATE OF MONTANA

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MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS
APRIL 1980

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NORTHERN PACIFIC RESERVOIR DAM

EXECUTIVE SUMMARY

A technical inspection team from Morrison-Maierle, Inc. along with respresentatives from the Montana Department of Natural Resources and Conservation and the Owner, American Smelting and Refining Company, (ASARCO), inspected the Northern Pacific Reservoir Dam on September 20, 1978 under authority of Public Law 92-367. The Northern Pacific Reservoir Dam is located on McClellan Creek in Jefferson County, approximately 2 miles south of East Helena, Montana. The project is located just upstream from Prickly Pear Creek, which is a tributary to the Missouri River. The findings presented in this report are based on visual inspection and personal interviews and additional investigations conducted by ASARCO's consultant noted in the letter dated 17 January, 1980 attached to this report. There are no known records or drawings pertaining to the dam. Procedures used in the safety analysis are accepted methodologies of public and private agencies engaged in this field as well as those established in the "Recommended Guidelines for Safety Inspection of Dams", U.S. Army Corps of Engineers.

PROJECT DESCRIPTION

The original Northern Pacific Reservoir Dam was a 20-foot high mortared rock dam constructed in the late 1800's. In 1935, the present concrete gravity structure was constructed over the existing rock dam. The new dam is 35 feet high, 165 feet long and was constructed with a slight arch. Virtually the entire effective length of the dam crest functions as an uncontrolled, overtopping, freefall spillway. Water is spilled down the face of the dam into a small plunge pool. Normal reservoir elevation is at the crest of the spillway, two feet below the crest of the dam. There are two outlet conduits, 24-inches square, through the dam which are inoperable and may be inaccessable at relatively low flows. The only known uses of the reservoir are as a water supply for the sprinkling of haul roads for an adjacent rock quarry, a settling basin for the quarry operation, and fish and wildlife habitat. All elevations used in this report refer to Mean Sea Level (M.S.L.).

FINDINGS AND EVALUATIONS

The Northern Pacific Reservoir Dam is a 35-foot high gravity concrete structure which is capable of impounding 150 acre-feet of water at the elevation of the spillway, National Geodetic Vertical Datum (NGVD, formerly Mean Seal Level). The dam has a maximum operating pool at the top of the dam, elevation 4002.29 feet, with an estimated storage capacity of 173 acre-feet (AF). Inspection

criteria classifies this dam as small in size and, because of possible downstream damage resulting from failure, the downstream hazard potential was initially considered as high. However, as a result of an engineering study conducted by ASARCO's consultant, the downstream hazard potential is re-classified to significant. Inspection criteria recommends such projects to safely handle a spillway design flood of 100-years to one-half the Probable Maximum Flood (PMF). Because of the assessed downstream risk potential it is recommended the project safely handle one-half the PMF. The PMF is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions reasonably possible in the watershed. The estimated PMF developed for this safely analysis was assumed to occur in a June-August period as a result of rainfall from a 6-hour thunderstorm event. This PMF has a peak discharge of 74,000 cfs and a total volume of 16,700 A.F.

For the flood routing, the initial reservoir pool was assumed to be at the spillway crest elevation 4000.0 feet. Because of inadequate storage and discharge capacity, the reservoir would rise to the top of the dam (elevation 4002.29 feet) in less than an hour adding 23 acre-feet of surcharge storage to the 150 acre-feet of normal storage at the spillway crest. At the time of overtopping the total discharge would have increased to 800 cfs. Using this combination of discharge and surcharge storage the project would handle less than one percent of the PMF volume before overtopping. When the reservoir rises above elevation 4002.3 feet, overflow of the right bank will occur. The effects of this overflow cannot be determined as subsurface conditions in this area are unknown. Severe erosion could possibly result leading to possible structural instability.

The concrete in the structure is in a generally deteriorated condition. Large areas on the downstream face of the right abutment have eroded away and concrete has deteriorated along the horizontal joints on the spillway face. Clear and free-flowing seepage was observed along the contact with bedrock at the right abutment which could affect the stability of the structure.

A preliminary stability analysis was performed using assumed parameters consistent with good engineering judgement and information collected during the inspection. The analyses shows at reservoir elevations ranging from the top of the dam to 4003 feet (one foot above the dam) accepted design criteria for overturning is exceeded and the dam could potentially fail. Under these conditions the discharge would be approximately 1200 cfs and less than two percent of the PMF volume would have entered the reservoir. Overturning is indicated when the reservoir reaches the 4013.5-foot elevation which occurs at a flow approximately equal to 45 percent of the PMF peak discharge.

Because of the significant downstream risk and lack of physical data with which to evaluate stability, the safety of the project is evaluated for the condition when design criteria is exceeded rather than when overturning is indicated. Failure of the structure during such relatively low flood flows would create a wave or surge downstream causing flooding, and extensive property damage as the surge traveled along the Prickley Pear Creek drainage through the City of East Helena and north into the rural Helena valley. Determining the magnitude of damage to East Helena and the valley is beyond the scope of this project. Northern Pacific Reservoir Dam does not meet inspection guidelines and is in need of immediate attention.

RECOMMENDATIONS:

1. Immediately prepare, implement and periodically test a downstream warning plan for use in the event of impending dam failure.

2. Immediately make the low flow outlet gates operational and maintain them in an operational condition so the reservoir can be drained for inspection, repairs and emergencies.

3. With the reservoir drained and no flow passing over the face of the dam, inspect the concrete for evidence of structural weakening and check seepage conditions through or under the dam. Make immediate interim corrective repairs if necessary for stability.

4. Conduct engineering studies to determine, and modify the discharge and/or storage capacities to safely handle, the one-half PMF.

5. Conduct detailed stability investigations including evaluation of foundation and abutment contact conditions, overbank erosion potential, seepage and structural integrity. Modify the project as required.

MORRISON-MAIERLE, INC.

Rodger C. Foster
Professional Engineer

PERTINENT DATA

NORTHERN PACIFIC RESERVOIR DAM

1.	GENERAL	
	Federal I.D. Number	MT - 858
	Owner	ASARCO
	Operator	ASARCO
	Purpose	Minor Recreation & Water Supply for Dust Control
	Location	U.S.G.S. Quad - East Helena T9N, R2W, Section 7
	County, State	Jefferson County, Montana
2.	RESERVOIR	
	Surface Area at Normal Pool	18 Acres
	Length of Normal Pool	1000 feet
	Storage at Normal Pool	150 acre-feet
	Surcharge storage (Spillway to Top)	23 acre-feet
	Maximum Storage at Dam Crest	173 acre-feet
	Drainage Area	33.6 sq. mi.
3.	SPILLWAY	
	Type	Uncontrolled overflow
	Crest Elevation	4000.0 feet (Assumed)
	Length of Crest	107 feet total
	Capacity at Top of Dam	800 cfs
4.	OUTLET STRUCTURE	
	Type	Two Square Outlets
	Control	Hand operated sluice gate
	Size	24 inches square
	Capacity	Not functional
5.	DAM	
	Type	Concrete Gravity Arch
	Hydraulic Height (Crest to Toe)	35 feet
	Crest Elevation	4002.29
	Crest Width	165 feet
	Upstream Slope	75°
	Downstream Slope	56°

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Northern Pacific Reservation Dam, owned by American Smelting and Refining Company (ASARCO).

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firm. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

The guidelines recommend a two-phased study procedure for investigation and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam.

(2) based upon an evaluation of the available data and a visual inspection.

(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted.

(4) not intended to include extensive explorations, analyses or to provide detailed alternative correction recommendations.

The details of Phase I recommendations must be developed in a Phase II investigation. The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam and

to develop the detailed correction recommendations. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulics and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The Corps has no authority to enforce the recommendations contained in the safety reports. The responsibility for implementation of the Phase I recommendations or initiating the Phase II studies rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action of failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of this inspection and subsequent report is to evaluate possible conditions that may threaten the integrity and structural stability of the Northern Pacific Reservoir Dam thereby creating potentially hazardous conditions to developed areas located downstream.

1.1.3 Inspection

This dam safety evaluation prepared by Morrison-Maierle, Inc., Helena, Montana, is based on information gathered during an on-site visual inspection of the dam and from interviews with representatives of ASARCO (owners of the dam), Burlington Northern, (owners of Northern Pacific Railroad), and Ed Maronick, longtime lessee of the land adjacent to the dam. Following the inspection, ASARCO contracted with Morrison-Maierle, Inc. to perform an engineering study of the downstream hazards associated with a dam failure. The results of that study are incorporated into this report. No historical data pertaining to the design, construction or maintenance of the dam was available, as the Northern Pacific Railroad discarded all such data when they returned the operation to the owners, ASARCO, in 1958. Procedures used during the 20 September 1978 inspection were in accordance with "Recommended Guidelines for Safety Inspection of Dams" established by the U.S. Department of the Army, Office of the Chief of Engineers, 1975. The personnel who formed the technical inspection team were the following:

Rodger Foster, P.E.	Project Manager, Morrison-Maierle, Inc.
Mike Kaczmarek	Chief Geologist, Morrison-Maierle, Inc.
C. William Keith, P.E.	Chief Structural Engineer, Morrison-Maierle, Inc.
Mark Weston, P.E.	Water Resource Engineer, Morrison-Maierle, Inc.

Others present during the inspection include:

Glen McDonald	Montana Department of Natural Resources and Conservation
Rod Kirchman	Representative from ASARCO

This report has been reviewed by ASARCO personnel and the Montana Department of Natural Resources and Conservation and their comments are included at the end of this report in the correspondence section.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

The gravity-arched concrete Northern Pacific Reservoir Dam is located in Section 7, Township 9 North, Range 2 West, Montana Principal Meridian, in Jefferson County, Montana. The dam is located on McClellan Creek and described as approximately on latitude 46°33.3' and longitude 111°54.3'. The location of the dam is illustrated on both the vicinity map (Plate 1) and the Drainage Basin Map (Plate 2). The existing gravity concrete structure is designed with an overflow spillway and two 24-inch square outlet gates. One small diversion dam on McClellan Creek used by the City of East Helena is located upstream from the Northern Pacific Reservoir Dam but is not identified by the National Dam Inventory Program. The Northern Pacific Dam is designated as MT-858 on the National Dam Inventory. The known current beneficial uses for the reservoir and dam are as a source of water for dust control in the local limestone mine, spill area for mine waste, and recreational fishing in the reservoir.

Northern Pacific Reservoir Dam is 35-feet high and impounds approximately 173 acre-feet at the dam crest elevation. Based on a visual reconnaissance, engineering judgement, and studies conducted by the ASARCO's Consultant, the ASARCO plant and the City of East Helena could be affected by a sudden branch of the dam.

1.2.2 Regional Geology

The Northern Pacific Reservoir Dam is located on the southeast margin of the Helena Valley. The Helena Valley is a structurally downfaulted and downwarped intermontane basin in the Rocky Mountains physiographic province of central Montana. The basin margins are flanked by mountainous terrain supported by complexly faulted and folded bedrock strata and massive igneous intrusive rocks.

The basin fill consists of unconsolidated to semiconsolidated Tertiary sediments estimated to be over 2,000 feet thick. Major stream drainages, principally Ten Mile Creek and Prickly Pear Creek, have deposited extensive fans of Quaternary alluvium in the south side of the basin. The Quanternary alluvium covers the Tertiary sediments in this area and is 80 to 120 feet thick near the southern margin of the valley. Other smaller drainages entering into the valley from the mountainous uplands, such as McClellan Creek, characteristically display alluvial floodplains incised through the Tertiary sediments which stand above the stream valleys as a low, gently sloping plain.

The Helena Valley is situated directly on a major structural trend which traverses the east-west length of the state of Montana. This structural trend is referred to as the Montana lineament at Helena. It aligns with other major lineaments which extend into Puget Sound and are believed to represent a major structure in the continental crust. Numerous smaller folds and faults of regional significance are associated with the Montana Lineament including several major faults in the Helena Valley. One large normal fault is projected across the south part of the Helena Valley 2 to 3 miles north of the Northern Pacific Reservoir and several small normal faults are present in the bedrocks about 1 mile west of the reservoir.

1.2.3 Seismicity

The Northern Pacific Reservoir Dam is located in seismic probability Zone 3. The seismic probabilities used here divide the United States into four seismic risk zones based on the record of the severity of ground shaking and the reasonable expectancy of earthquake damage. Seismic probability (or risk) in Zone 3 indicates that major destructive earthquakes may occur. Zone 3 corresponds to a potential intensity of VIII and higher on the Modified Mercalli intensity scale of 1931.

The Helena Valley has an extensive history of earthquake activity. The first record is of an intensity VI shock in Helena on May 22, 1869. In 1872, intensity VI shocks occurred at Helena on December 10 and December 11. In October and November of 1935 a series of 1,347 shocks and aftershocks raging from maximum intensities of V to X and including magnitude 6 and magnitude 6.25 earthquakes (Richter magnitude scale) rocked the Helena area causing four deaths, several injuries, and property damage exceeding $4 million.

Stresses on the Northern Pacific Reservoir Dam due to seismic loading will probably be limited to bedrock acceleration. Field inspection of the damsite did not reveal any faults or bedrock discontinuities that might result in differential stresses in the foundation strata. Under these conditions the "Recommended Guidelines for Safety Inspection of Dams" recommends an acceleration coefficient of one-tenth of gravity in the seismic stability analysis.

1.2.4 Site Geology

The Northern Pacific Reservoir is located on the alluvial floodplain sediments of McClellan Creek. The McClellan Creek alluvial fill and floodplain valley at the dam and reservoir site is incised into the Tertiary sediments along their contact with the Paleozoic bedrocks at the edge of the Helena Valley. The thickness of the alluvium under the reservoir site is unknown. The alluvium is confined to the physiographic floodplain of McClellan Creek, being bounded on the left by Meagher Limestone and on the right by Tertiary sediments (Plate 6). No areas of slope failure or other geologic hazards were observed in the reservoir area and no faults were observed at the damsite.

1.2.5 Description of Dam and Appurtenances

For the purpose of describing the dam and appurtenances, a convention has been adopted which describes relative locations in reference to looking downstream; i.e., the northeast abutment is the right abutment as viewed looking downstream and the southwest abutment is the left abutment. Several photographs of the dam taken during the inspection are presented following the text of this report.

The gravity, arched concrete dam rises approximately 35 feet above the creek bottom and has a 3-bay overflow spillway (Photo 1, Plate 3). The radius of curvature of the arch of the dam is approximately 200 feet. The right abutment has no arch and is 51.7 feet long. The right, center, and left spillway bays are 31.0, 46.3 and 29.7 feet long, respectively. The right and left piers are 3.0 feet wide and serve as the base for the handwheel used for operating the outlet gates. The crest length from the bedrock at the left abutment to the left spillway is less than a foot. The breadth of the crest of the dam and of the spillway crest is 1.8 feet.

Water flowing over the spillways impinges on the 56° sloping face of the dam. The creek bottom at the toe of the dam is composed of gravel and large boulders of apparent bedrock material. The dam has two, 24-inch square conduits discharging approximately 10 feet above the creek bottom. These outlets are located directly below the two piers and are controlled by sluice gates mounted on the upstream face of the dam.

The top of the dam is approximately 2.3 feet above the spillway crest which is at an estimated elevation of 4,000 feet N.G.V.D. as determined from a 15 minute USGS quadrangle map. A detailed survey was not made to establish precise reference elevations to the USGS datum. The upstream face of the dam has a slope of 78°. The reservoir formed by the dam covers approximately 18 surface acres and stores

an estimated 150 acre-feet of water at the elevation of the spillway crest. The storage volume reflects a somewhat reduced capacity as the reservoir appears to have had a large degree of sedimentation occur, particularly in the left abutment area where waste material generated by the local limestone mining operation has been deposited. It is not actually known how sedimentation has affected the storage volume.

1.2.6 Design and Construction History

In the late 1800's a mortared rock dam was constructed on McClellan Creek at the site of the existing Northern Pacific Reservoir Dam. This dam was a gravity structure 8 feet wide at the crest and approximately 20 feet high.

In the 1920's ASARCO purchased the land which included the dam site and reservoir. In 1935, the dam was reconstructed and raised 15 feet by the Northern Pacific Railraod. The original rock and concrete structure was encased by the new concrete dam. The structure that exists today is the one that was constructed in 1935. One year after the dam was raised in 1935 upon order from the Montana State Fish and Game Department, the Northern Pacific Railraod constructed a wooden fish ladder. The fish ladder was constructed on the far right edge of the right spillway. The fish ladder fell into a state of disrepair and today only a couple of support beams remain where the fish ladder attached to the dam.

A railroad trestle just upstream from the dam was constructed across the reservoir. This trestle allowed the transporting of limestone by rail, from the mine to the ASARCO Smelter in East Helena. In 1958 Northern Pacific Railroad withdrew their association with the dam and the mine. Maronick Construction Co., the contracted operators of the limestone mine, removed the railroad trestle and replaced the crossing with an earthen causeway approximately 200 feet upstream from the dam. The causeway across the reservoir is the only access for transporting limestone from the mine. Water passes through the causeway by means of a 78-inch corrugated metal culvert. In 1958 when Northern Pacific Railroad withdrew their association with the dam, they discarded and destroyed all drawings and historical records for the dam.

1.2.7 Physiography, Climatology and Hydrology

The drainage basin above Northern Pacific Reservoir covers 33.6 square miles and has a teardrop shape. McClellan Creek, the principal stream channel, extends approximately 12 miles south from the reservoir. The majority of the watershed is mountainous with elevations ranging from 4,000 feet at the dam to 8,000 feet along the divide crest. Eighty-five percent of the watershed is forested and fifteen percent lies in grasslands.

Southwestern Montana has a continental climate with warm summers and cold winters. The average temperature at the Helena Airport for January and July are 25°F and 68°F respectively. Average annual precipitation varies from 14 inches at the dam to 30 inches at the higher watershed elevations.

The majority of runoff from the Northern Pacific basin occurs during the late spring - early summer period. Normally, flow recedes through the summer and fall months and reaches an ebb during the winter months. Summer thunderstorms or fall rains can cause temporary periods of increased runoff.

1.2.8 Project Operation and Maintenance

The responsibility of operation and maintenance of the dam is with ASARCO, the owner. The dam has two outlet gates which are only accessible by walking across the spillway. The right gate was last operated in 1977. The left gate is believed to be covered with silt and is inoperable. The reservoir is operated at full pool (spillway crest elevation 4000.00 feet N.G.V.D.).

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 SPILLWAY DESIGN FLOOD

Inspection criteria classifies this dam as small in size and, because of possible downstream damage resulting from failure, the downstream hazard potential was initially considered as high. However, as a result of an engineering study conducted by ASARCO's consultant, the downstream hazard potential is reclassified to significant. Inspection criteria recommends such projects to safely handle a spillway design flood (SDF) of 100-years to one-half the Probable Maximum Flood (PMF). Because of the assessed downstream risk potential, it is recommended the project safely handle one-half the PMF.

2.2 HYDRAULICS AND STRUCTURES

2.2.1 Hydraulics

Approximately 107 feet of the total crest length of the Dam (165 feet) acts as an uncontrolled overflow spillway. The spillway crest is at elevation 4000.0 feet M.S.L. (2 feet below dam crest) and consists of 3 bays separated by two 3-foot wide piers (see Plate 6). The entire 165-foot wide dam crest is an uncontrolled overflow structure when the reservoir rises above dam crest. The capacity of the spillway at dam crest is 800 cfs. The spillway is assumed to act as a broadcrested weir with two end piers and two intermediate piers. A discharge rating curve for the dam is presented on Plate 5. The spillway crest has a breadth of 1.80 feet and varies in condition from poor to fair. The downstream face of the dam slopes at approximately 1½ vertical on one horizontal (56°). Water discharging over the spillway impinges on the downstream face of the dam and falls into a small naturally-formed plunge pool at the dam's toe.

Discharges at elevations above the dam crest will completely overtop the structure and force overbank flow in the vicinity of the right abutment. Without exploration in the right overbank area to determine the nature of the material, judgements as to the erodibility of material and effects on the right abutment cannot be made. Right overbank flow occurs at flows greater than 800 cfs. No records of reservoir elevation are kept by the owner that might indicate overbank flow has occurred. McClellan Creek maintains an inflow to the reservoir throughout the year and all inflows at the reservoir must be discharged over the spillway due to inoperable outlet gates. A stage-storage curve (Plate 4) was estimated using topography from the East Helena USGS quad sheet and the conic method of computing

storage presented in the U.S. Army Corps of Engineers' "HEC-1 Users Manual for Dam Safety Investigations".

A stage-discharge curve was developed for gross dam overtopping situations (Plate 5) using a weir discharge equation and accounting for overbank flow around the right and left abutments. Weir coefficients were varied with head from values of 2.7 to 3.8 to reflect the increased unit discharge at the higher heads. A hydraulic model study would be required to accurately predict all flow phenomenon that would occur with large project discharges.

2.2.2 Outlet Works

The outlet works consist of two 24-inch square conduits formed into the structure during construction. These outlet conduits are located directly below each spillway pier. Each conduit has an invert elevation 24 feet below the dam crest. They are controlled by sluice gates mounted on the upstream face of the dam which are manually operated by wheels mounted on the piers. Because of their inaccessible location, the outlet gates would not be operable during high flows. It was mentioned by Mr. Ed Maronick that the left outlet gate may be buried with waste material from an adjacent mining operation. During the inspection, both gates were frozen closed and could not be opened. Because the outlet gates are inoperable they were not included in the project outflow capabilities during flood routing.

2.2.3 Freeboard

The dam is operated as an uncontrolled overflow spillway with two feet of vertical distance between the spillway crest and the top of the dam. Freeboard does not exist with the recommended spillway design flood. Wind generated waves would be negligible due to the short fetch and the effects of the road fill across the reservoir.

2.2.4 Causeway

A compacted gravel and earthen causeway has been constructed across the reservoir approximately 200 feet upstream from the dam face. Wind-generated waves in the reservoir are dissipated at this structure. The top of the causeway is at elevation 4004.8 feet M.S.L. One 78-inch corrugated metal pipe culvert provides flow through the causeway. The hydraulic capacity of the culvert is approximately 400 cfs. At flows greater than 400 cfs the causeway will be overtopped and eroded in a short time. During significant flood flows, the causeway would be washed away and have no effect on flood routing.

2.3 HYDROLOGY

2.3.1 Estimated Probable Maximum Flood

A 6-hour June-August thunderstorm event applied to the 33.6 square mile drainage would present the most critical storm conditions for the Northern Pacific Reservoir Dam. The Probable Maximum Precipitation (PMP) corresponding to such a storm was determined using procedures outlined in the Weather Bureau Technical Paper No. 38. Precipitation for the 6- hour PMP thunderstorm totals 10.0 inches. A minimum constant soil infiltration loss rate of 0.15 inches per hour was used because of the possibility of a thunderstorm occurring during the 24 hours prior to the PMP and saturating the watershed. This storm event was divided into 10-minute increments and arranged in a critical time sequence.

A unit hydrograph was developed for the relatively steep drainage using procedures outlined in the Design of Small Dams (U.S. Dept. of Int., 1977). Using the U.S. Army Corps of Engineers' "Flood Hydrograph Package, (HEC-1)", the unit hydrograph and precipitation values were combined to produce a PMF hydrograph from the 6-hour storm duration. This analysis produced a PMF peak discharge of 74,000 cfs with a volume of 16,700 acre-feet. Also, to assess the capabilities of the dam, five ratios of the PMF hydrograph were developed and routed through the reservoir.

2.3.2 Routing of the Flood

The Reservoir is normally operated at the spillway crest elevation and, because of limited surcharge storage, has virtually no effect on the routing of high flows. Peak outflows closely match peak inflows. A 0.5 PMF applied 24 hours prior to the PMF would add little or no surcharge to the reservoir. Therefore, for the flood routing analyses it was assumed the starting pool elevation would be at the spillway crest. A 0.1 PMF overtops the spillway crest by approximately 6 feet, a 0.5 PMF overtopped by 14.5 feet and a full PMF overtops the spillway crest by 21 feet. The capacity of the immediate downstream channel was computed and found to be approximately equal to the PMF peak flow. A rating curve was developed for the channel to determine tailwater elevations for use in the dam stability analyses. The computed tailwater elevations reflect supercritical flow downstream and minimum tailwater conditions.

2.4 STRUCTURAL CONDITIONS AND STABILITY

2.4.1 General Dam Conditions

General conditions of the structure are illustrated in the photographs which were taken during the inspection and are presented following the text of this report. A visual inspection of the dam

did not reveal any significant vertical or horizontal movement; however, the dam is constructed along a slight horizontal curve which made exact determination of any horizontal movement impossible. The dam does not appear to have been constructed in blocks, but appears to have been built in vertical lifts of approximately two feet. At the interface of many of these lifts significant deterioration of the concrete and slight seepage was observed. The presence of water spilling over the face of the dam however, made it impossible to determine the exact extent of this seepage.

The crest of the spillway is in fair to poor condition and concrete has been eroded away at the crest on two of the spillway bays (Photo 2). The piers also show deterioration of the concrete at the crest (Photos 10 and 11). The face of the dam shows varying degrees of concrete deterioration. Deterioration at the joints between the apparent poured lifts was also observed (Photo 7). Major visible cracks were not observed. However, surface cracks were noticed in the concrete near the right abutment (Photo 6). In the observed cracking areas and eroded areas, minor vegetative growth was observed (Photos 9 and 10). The deterioration of the dam face appears to be widespread rather than isolated to any particular area.

2.4.2 Foundation

The foundation of the Northern Pacific Reservoir dam apparently consists of Meagher Limestone striking S 31° W and dipping 32 to 35 degrees south. The limestone is very hard, light gray, and contains interbedded laminae of gold-colored silty limestone giving it a bedded appearance in section and a gold mottled appearance in plan. The limestone is cut by two major joint systems, one striking N 85° W and dipping 78° north on 48-inch centers and one striking N 10° W and dipping 85° north on 60-inch centers. Both joints are paralleled by weakly developed partings on approximately 12-inch spacings. Based on exposed limestone at and near the dam abutments, the dam appears to be founded on bedrock. However, the exact nature and extent of foundation preparation is unknown. A small plunge pool 3 to 4 feet wide and 4 feet deep in the bedrock is evident below the spillway. However, by probing with a survey rod no evidence of undercutting was observed.

2.4.2.1 Seepage

Significant seepage was observed along the contact of the right abutment from approximately the reservoir pool elevation down to the point where spillway discharge was present. The rate of seepage increased from the top to the bottom of the seepage zone and was estimated to be 40 to 50 gallons per minute. Seepage was discharging through the interface between the bedrock limestone and the concrete dam. No evidence of natural solution cavities or post dam solution

exploitation of joints or fractures was detected. No seepage was observed through joints in the limestone. The only seepage was at the dam-bedrock interface. Seepage could not be observed on the foundation or left abutment due to spillway discharge over these areas.

2.4.2.2 Right Abutment

The right abutment consists of Meagher Limestone overlain by Tertiary Sediments. The sediments have been removed down to limestone bedrock along the abutment and foundation and the concrete interface with the bedrock exposed except for the last 10 to 15 feet of the right end of the structure. The extent of bedrock preparation such as grouting or keyway construction is unknown. Ledges of limestone protrude into the concrete; however, these may penetrate newer concrete poured over an older structure and provide no clue to keyway or foundation preparation.

2.4.2.3 Left Abutment

The left abutment also consists of Meagher Limestone; however, the bedrock is covered by limestone debris and talus on this abutment. The degree of abutment and foundation preparation and keyway cutting is unknown and not displayed. The concrete on the left end of the dam is covered by the same rock debris that obscures the abutment bedrock. An outcrop of Meagher Limestone above the abutment and about 200 feet downstream strikes S 31° W and dips 35 degrees south. This outcrop appears to be substantially the same as the bedrock on the right abutment.

2.4.3 Dam Stability

The dam was analyzed for stability as a gravity section for pool elevations ranging from 4000.0 feet (top of spillway crest) to 4014.5 feet at the one-half PMF. The structure was assumed to rest on but not be keyed into bedrock. Lateral support from the canyon walls was discounted and any added stability from arch action was ignored. The full dam section was analyzed for stability against sliding and overturning on the rock base. Also the stability of one partial section was checked assuming separation along a horizontal construction joint 21.7 feet below the spillway crest. This joint corresponds to horizontal lines on the face of the dam which show heavy deterioration of the concrete.

The criteria used in assessing the stability of the dam are consistent with accepted design practices. For stability against overturning, a dam is considered within safe limits if the resultant force resisting overturning falls within the middle third of the base of the dam. For stability against sliding under extreme loading conditions, the dam is considered within safe limits if the

safety factor for resistance to sliding, considering friction and shear, is greater than 1.5. For seismic forces some concession in factor of safety can be made.

Since no design or construction data is available for the dam, many engineering assumptions were made in the stability analysis. The general assumptions are:

a. There is no reinforcing steel in the dam section.
b. The unit weight of concrete is 145 pounds per cubic feet.
c. The compressive strength of concrete is 2000 pounds per square inch (PSI).
d. The allowable shear stress in the concrete under sliding condition is based on ACI 318-63, $fv = 2\sqrt{f'c} = 89$ psi.
e. The coefficient of friction equals 0.70.
f. Uplift pressure at the horizontal faces is 100 percent of the upstream pressure decreasing to zero or to the tail water pressure at the toe.
g. When the resultant of forces falls outside the middle third of the base, the reduced area which resists sliding by shear is that area which remains in compression.
h. The more recent concrete overlay will act monolithicly with the original mortared rock dam.
i. The height and slope of the upstream face are as estimated during the inspection.
j. Silt has accumulated behind the dam to within 10 feet of the spillway crest.
k. Under seismic loadings the reservoir would be at normal pool (4,000 feet) and the acceleration equals one-tenth the acceleration of gravity.

The stability analysis indicates that when the pool elevation is two to three feet above the spillway crest, (elevations 4002 to 4003 feet,) the resultant force on the dam falls outside the middle third of the base and the safety criteria for overturning is exceeded. The flow over the dam at this point is approximately 1,200 cfs which is less than two percent of the PMF peak discharge. When the pool reaches 4013.5 feet, at approximately 45 percent of the PMF peak discharge, the resultant force falls outside the base of the dam and failure due to overturning is indicated. The analysis for stability against sliding indicates the safety criteria is exceeded when the pool reaches elevation 4013.8 feet.

Under seismic loading conditions the safety factor against sliding is greater than 5 and the force resisting overturning falls essentially at the two-thirds point of the dam base. The stability of the dam is adequate for seismic loadings according to criteria presented earlier in this section.

The stability analyses indicates the dam is more likely to fail by overturning than by sliding. Although the stability analyses indicates overturning of the dam would occur at flow conditions approaching one-half the PMF in magnitude, a potential for failure exists when design criteria is exceeded which occurs during a significantly smaller flood event. According to present design standards, stability is inadequate for flows greater than about two percent of the PMF at which point the dam is unstable.

2.5 PROJECT OPERATION AND MAINTENANCE

ASARCO, the owners, are also the operators of the dam. There is no operation or maintenance plan or strategy for the Northern Pacific Reservoir Dam. The Maronicks, local residents, last operated one of the outlet gates in 1977. Seepage through the right abutment was noticed during our safety inspection and evidence of remedial attempts to control the seepage with sheets of vinyl was observed. The repair attempts apparently have not been successful.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

The Northern Pacific Reservoir Dam, being 35-feet high with a storage capacity of approximately 150 acre-feet, is classified as small in size. If a sudden failure of the dam was to occur, extensive property damage to East Helena and the ASARCO plant could occur. Therefore, Northern Pacific Reservoir Dam is classified as having a significant downstream hazard potential. For dams of this category the guidelines recommend the spillway capacity be a 100-year flood to a one-half PMF. However, due to the potential for extensive property damage, it is recommended that a one-half PMF be used for the Spillway Design Flood (SDF).

The capacity of the spillway is approximately 800 cfs with the reservoir pool elevation at the top of the dam. The entire dam acts as a spillway when water levels reach elevation 4002. When water levels rise above elevation 4002, water begins to overflow the right abutment. Considerable overbank flow occurs at elevations greater than 4006.

The exposed concrete along the spillway crests and downstream face of the dam is generally in a deteriorated condition. Major cracks were not observed. However, surface cracks were noticed and widespread erosion of the concrete surface exists. The upstream face was not visible due to the level of the pool. Deterioration of the downstream face and spillway will continue without corrective maintenance.

Access to the outlet gate controls is difficult to impossible because, to reach them, one must walk on the spillway sill while water is spilling. At the time of the inspection, the outlet gates were frozen closed and inoperable. It was reported that the gates may be covered by mine waste material deposited from the limestone mine adjacent to the reservoir.

The Northern Pacific Reservoir Dam appears from the inspection to be constructed on geologically sound abutments and foundation materials. Geologic structures including bedding and joints are oriented to resist failure under compressive normal loads or shear loading imposed by forces on the upstream face of the dam. The location and extent of the limestone bedrock in the subsurface to the right (east) of the dam is unknown. Overtopping of the dam might result in rapid erosion of the unconsolidated sand and gravel adjacent to the right abutment unless resistant bedrock is present in the subsurface. Such erosion might affect structural stability.

The seepage observed on the right abutment is suspected to be present under the remainder of the structure. There is no erosion or piping hazard associated with this seepage. However, the uplift pressure imposed on the base of the dam by this seepage does affect the stability.

The stability of the dam structure was checked for overturning and sliding under various flow conditions and for stability due to seismic activity. For flows greater than two percent of the PMF the resultant of all forces on the dam falls outside of the middle third of the base of the dam which exceeds stability criteria by present design standards. As flows approach 0.5 PMF the resultant of all forces on the dam falls outside of the limit of the base which indicates failure due to overturning.

Because of the risks associated with the downstream effects of failure, the safety of the Northern Pacific Reservoir Dam is evaluated for the conditions when design criteria is exceeded or at approximately two percent of the PMF. It is at this point that the dam fails to meet recommended safety criteria. If the dam should fail at this point, with the reservoir three feet higher than the spillway crest, the flood surge could cause extensive property damage to the community of East Helena, local industry, important public utilities, highways and railroads.

3.2 RECOMMENDATIONS

The investigation findings require a high priority be given to the following recommendations.

3.2.1 Immediately prepare, implement and periodically test a downstream warning plan for use in the event of impending dam failure.

3.2.2 Immediately make the low flow outlet gates operational and maintain them in an operational condition so the reservoir can be drained for inspection, repairs and emergencies.

3.2.3 Prepare and implement an operation and maintenance plan and schedule periodic inspections at least once every five years by engineers experienced in dam design and construction.

3.2.4 Inspect and repair deteriorated concrete and cracks to prevent continued structural weakening.

3.2.5 Monitor and evaluate seepage conditions when there is no flow over the dam to obscure the condition. If necessary for stability and safety, correct seepage problems, such as that presented at the right abutment.

3.2.6 Monitor the plunge pool scour hole until such time that the spillway flows are directed away from the toe. This monitoring is intended to insure that timely and appropriate action is initiated should the scour hole migrate to threaten the dams foundation.

The above recommendations will not make the project meet the guideline safety criteria but will provide a small margin of safety during the interim period while studies and modifications to bring the project into guideline compliance are being accomplished.

3.2.7 Conduct engineering studies to determine one-half the PMF, design project modifications, and modify the discharge and/or storage capacities to safely handle one-half the PMF.

3.2.8 Conduct detailed stability investigations including evaluation of foundation and abutment contact conditions, geologic structure of right overbank area and seepage and structural integrity. Modify the project as required to provide the necessary stability.

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O'Leary, Don; past employee of Northern Pacific, employee of Burlington Northern-St. Paul, personal communication Sept. 22, 1978.

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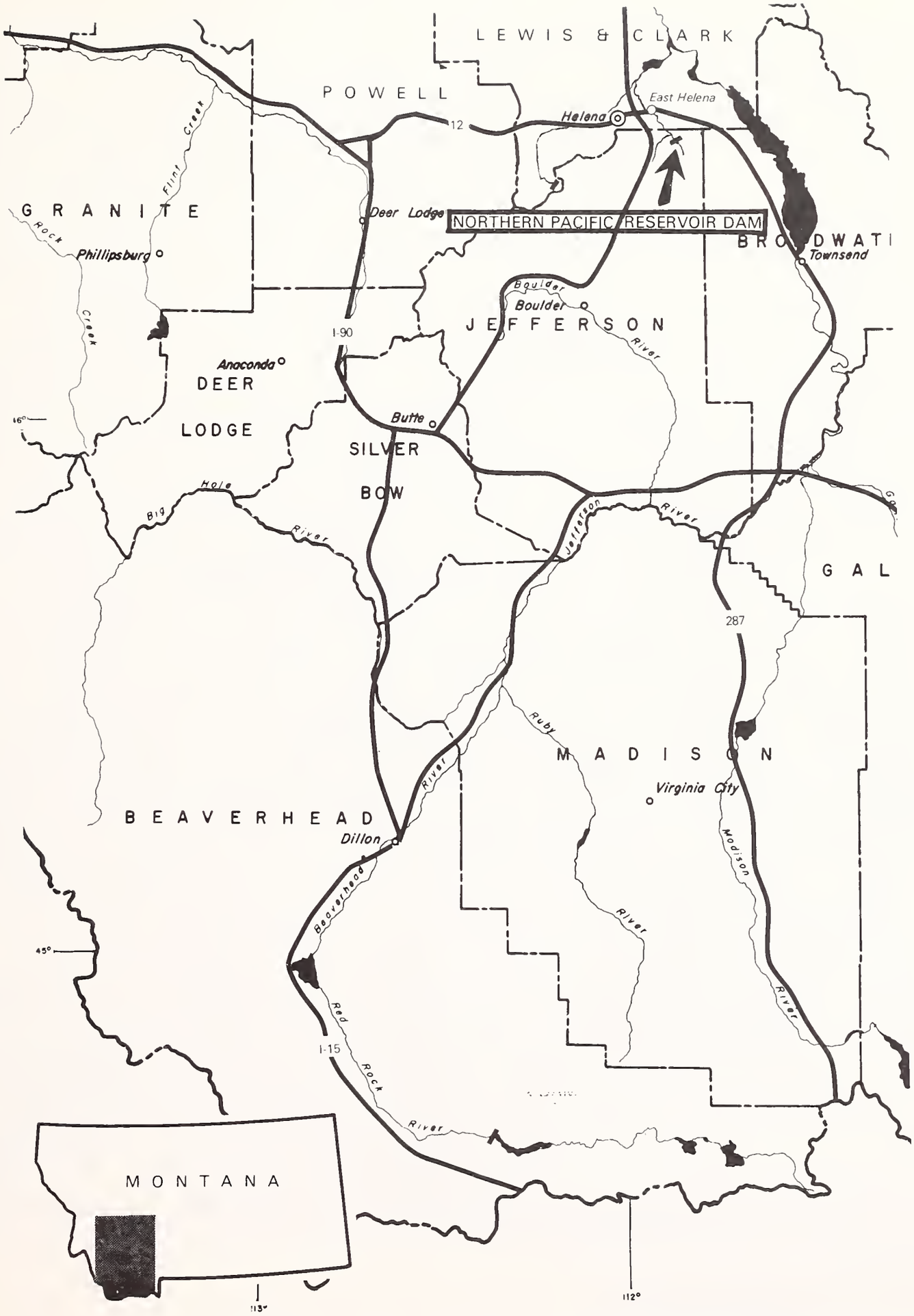


PLATE 1 NORTHERN PACIFIC RESERVOIR DAM VICINITY MAP

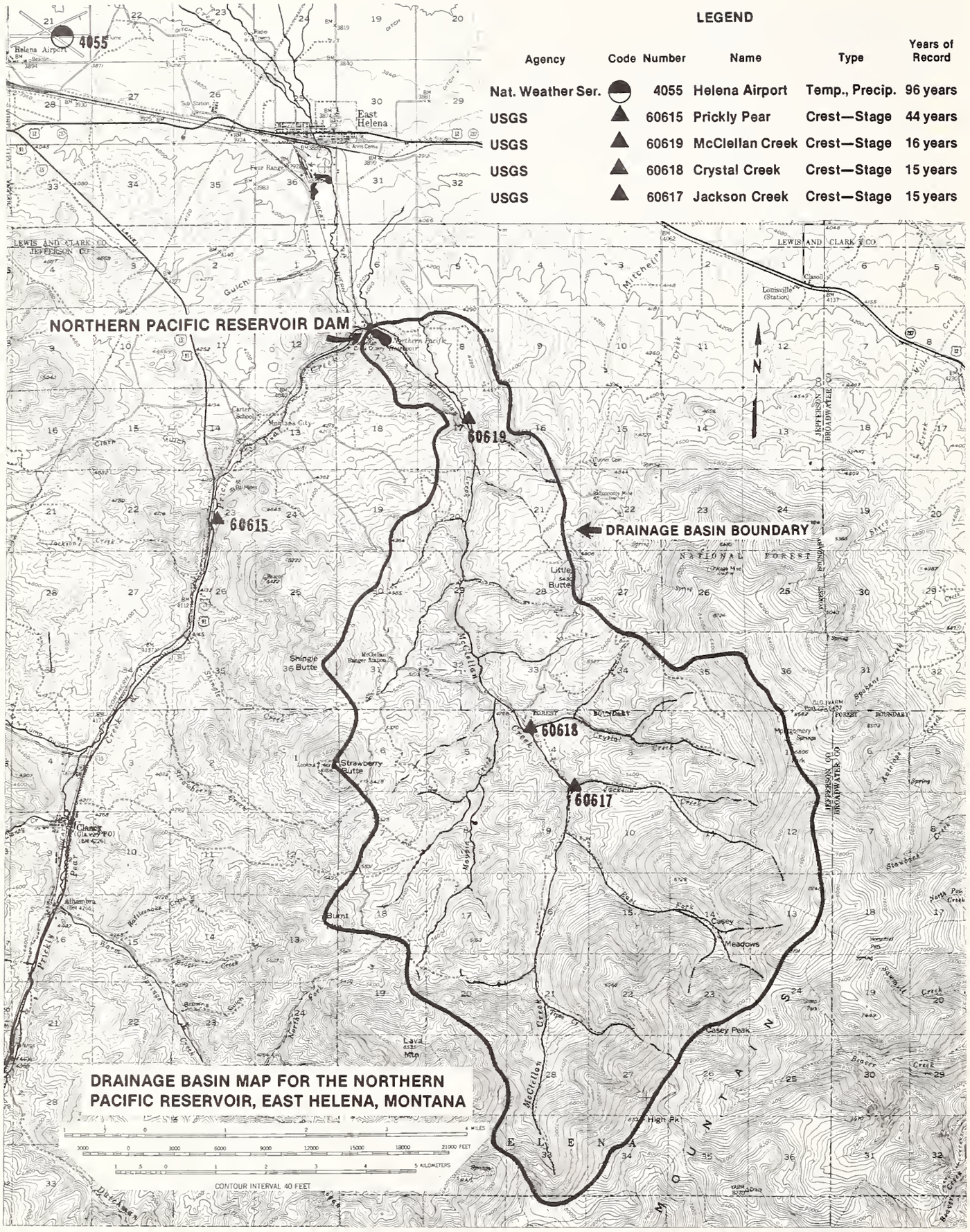
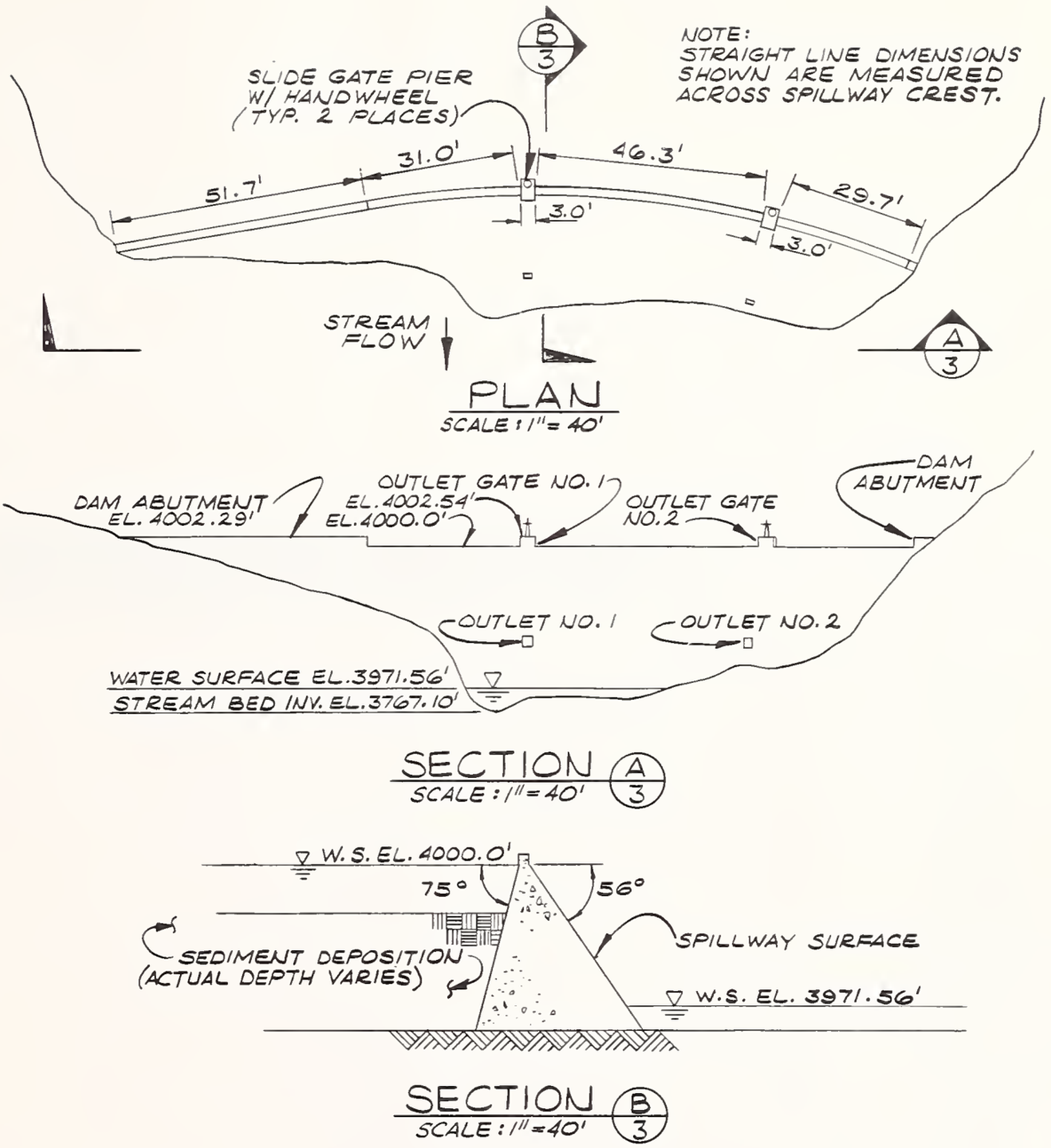

LEGEND
Agency | Code Number | Name | Type | Years of Record
Nat. Weather Ser. | 4055 | Helena Airport | Temp., Precip. | 96 years
USGS | 60615 | Prickly Pear | Crest—Stage | 44 years
USGS | 60619 | McClellan Creek | Crest—Stage | 16 years
USGS | 60618 | Crystal Creek | Crest—Stage | 15 years
USGS | 60617 | Jackson Creek | Crest—Stage | 15 years
NORTHERN PACIFIC RESERVOIR DAM
DRAINAGE BASIN BOUNDARY
4055
60619
60615
60618
60617
Helena Airport
East Helena
Montana City
Shingle Butte
Strawberry Butte
Little Butte
Casey Peak
Lava Mtn
High Pk
Clancy
Jackson Creek
Crystal Creek
McClellan Creek
Prickly Pear
Meadows
LEWIS AND CLARK CO.
JEFFERSON CO.
BROADWATER CO.
NATIONAL FOREST
E L E N A M O U N T A I N S
DRAINAGE BASIN MAP FOR THE NORTHERN PACIFIC RESERVOIR, EAST HELENA, MONTANA
CONTOUR INTERVAL 40 FEET

PLATE 2
DRAINAGE BASIN MAP



NOTES:

1) APPROXIMATE ELEVATION AT SPILLWAY IS 4000 FEET ABOVE MEAN SEA LEVEL. 97.80' ≈ 4000.00'

2) ARCH OF DAM RADIUS IS APPROXIMATELY 200 FEET.

3) UPSTREAM FACE SLOPE ON DAM = 75°
DOWNSTREAM FACE SLOPE ON DAM = 56°

4) INVERT ELEVATION OF OUTLETS = 3978.30' (OUTLETS 2'-0" SQ.)

5) WIDTH OF SPILLWAY CREST = 1'-10" (TYPICAL)

6) DAM HEIGHT ≈ 35 FEET

7) UPSTREAM WATER SURFACE ELEVATION 4000 FEET

PLATE 3
SKETCH OF DAM

STAGE—STORAGE CURVE FOR THE NORTHERN PACIFIC RESERVOIR, EAST HELENA, MONTANA

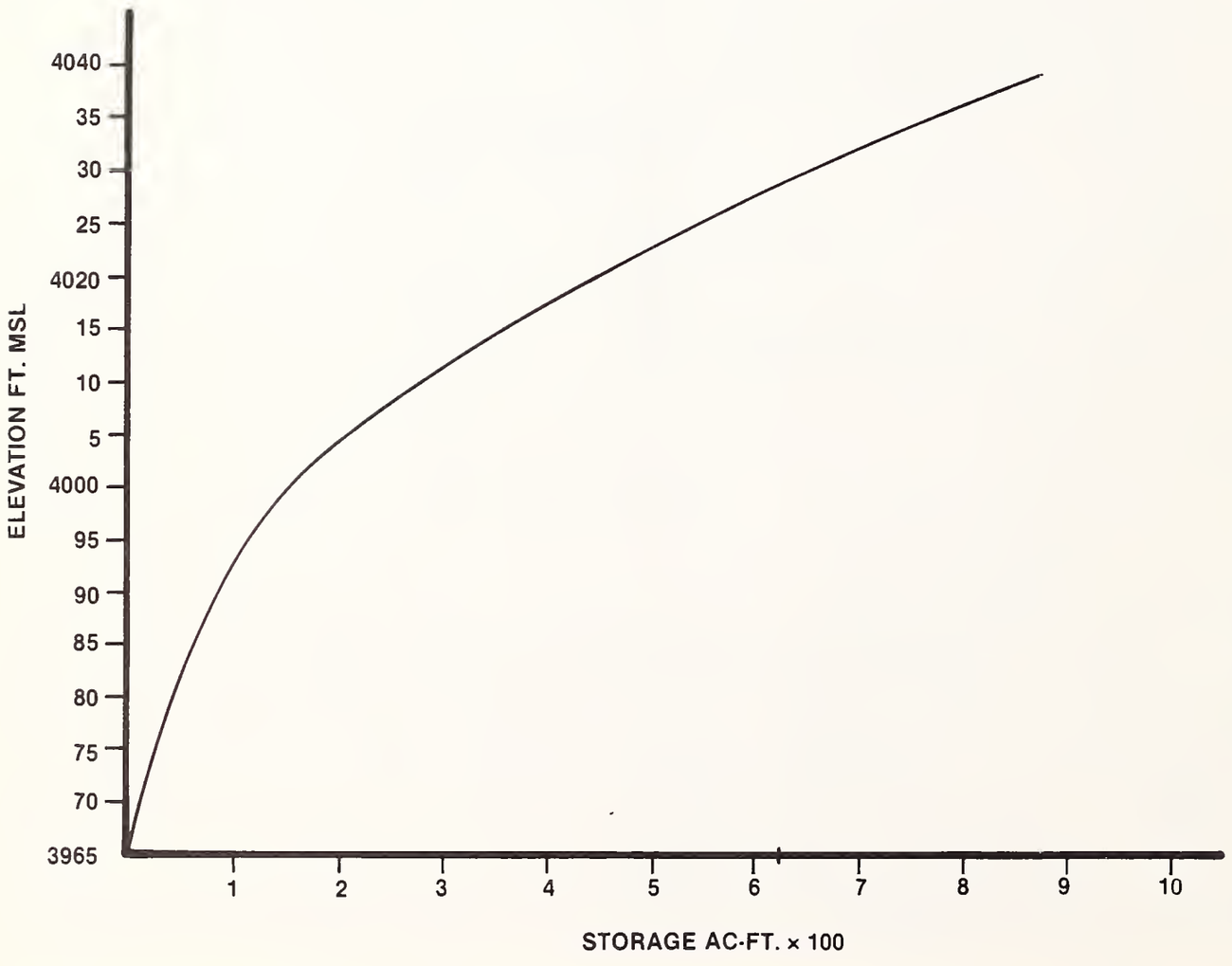


PLATE 4
STAGE — STORAGE CURVE

DISCHARGE RATING CURVE FOR THE NORTHERN PACIFIC RESERVOIR DAM, EAST HELENA, MONTANA

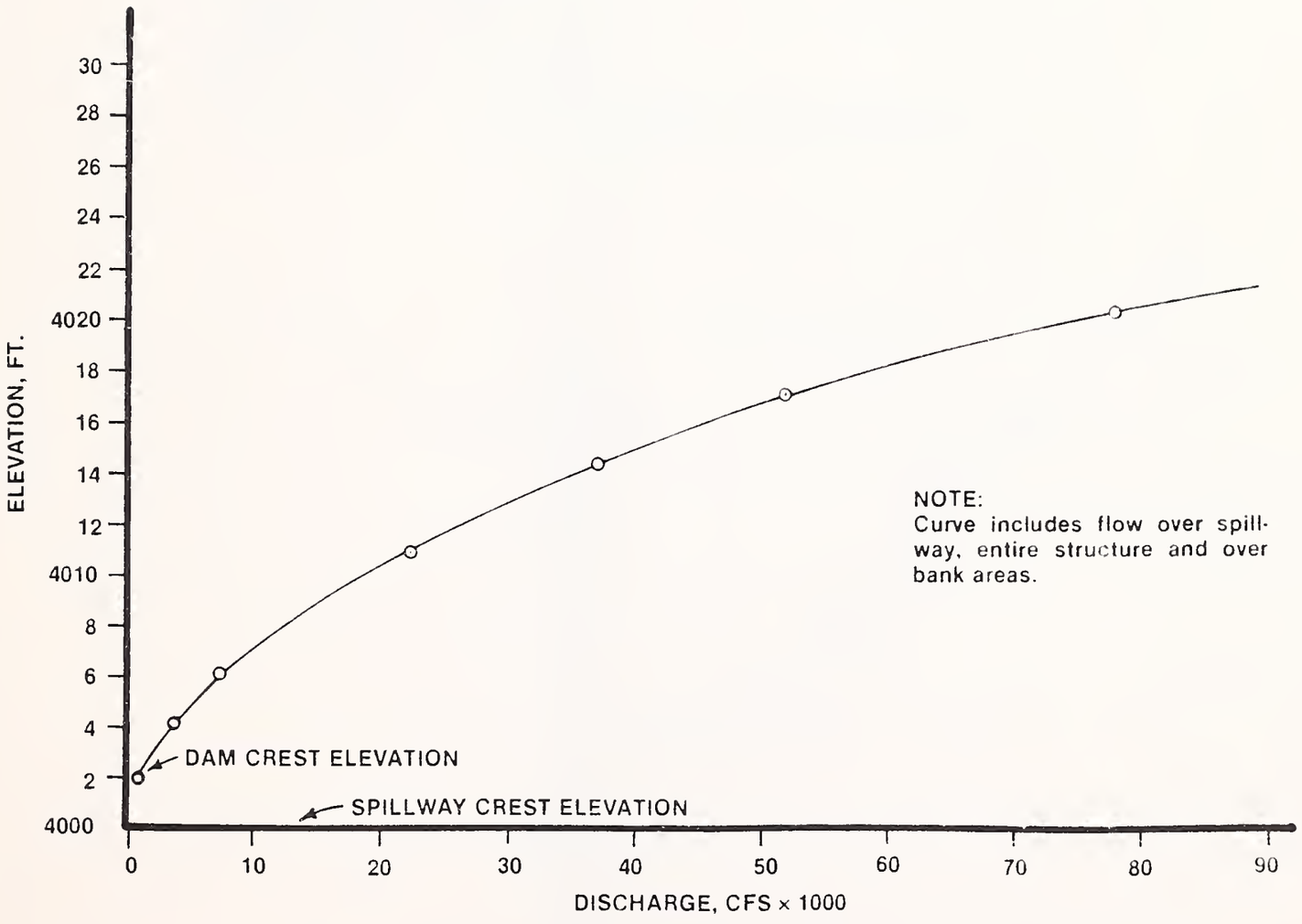
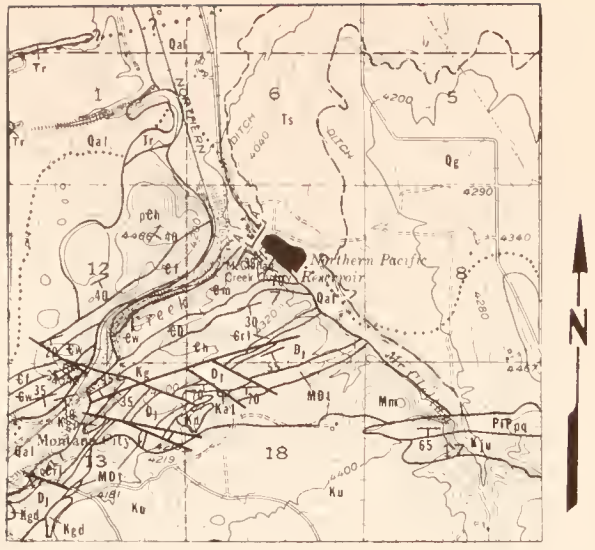


PLATE 5
DISCHARGE RATING CURVE



EXPLANATION:

SEDIMENTARY ROCKS

- Qal ALLUVIUM
- Qg HIGH LEVEL GRAVEL
- Ts TERTIARY SEDIMENTS
- KJu CRETACEOUS AND JURASSIC UNDIFFERENTIATED
- P pq PHOSPHORIA AND QUADRANT FORMATIONS
- Mm MADISON GROUP
- Dt THREE FORKS FORMATION
- Dj JEFFERSON FORMATION
- €r RED LION FORMATION
- €h HASMARK DOLOMITE
- €p PARK ARGILLITE
- €m MEAGHER LIMESTONE
- €w WOLSEY FORMATION
- €f FLATHEAD QUARTZITE
- p€h HELENA DOLOMITE

IGNEOUS ROCKS

- Tr RHYOLITE
- Kgd GRANODIORITE

GEOLOGIC CONTACT
INFERRED CONTACT BETWEEN Ts AND BEDROCK
NORMAL FAULT
25 STRIKE AND DIP OF BEDS
ARTIFICIAL FILL

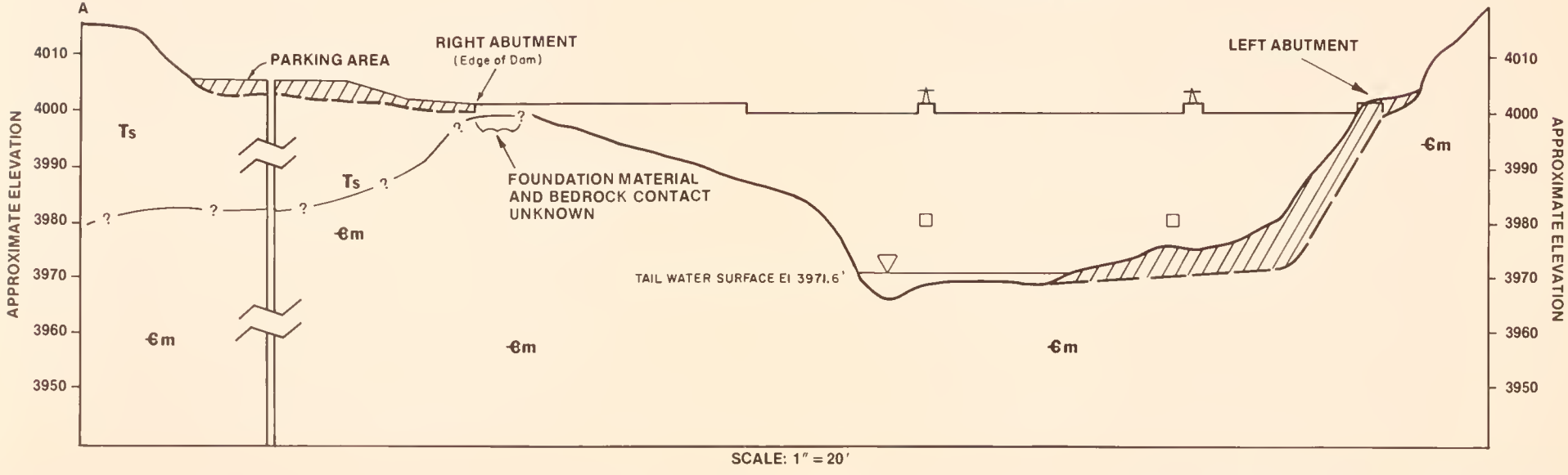


PLATE 6 GEOLOGIC MAP AND CROSS SECTION

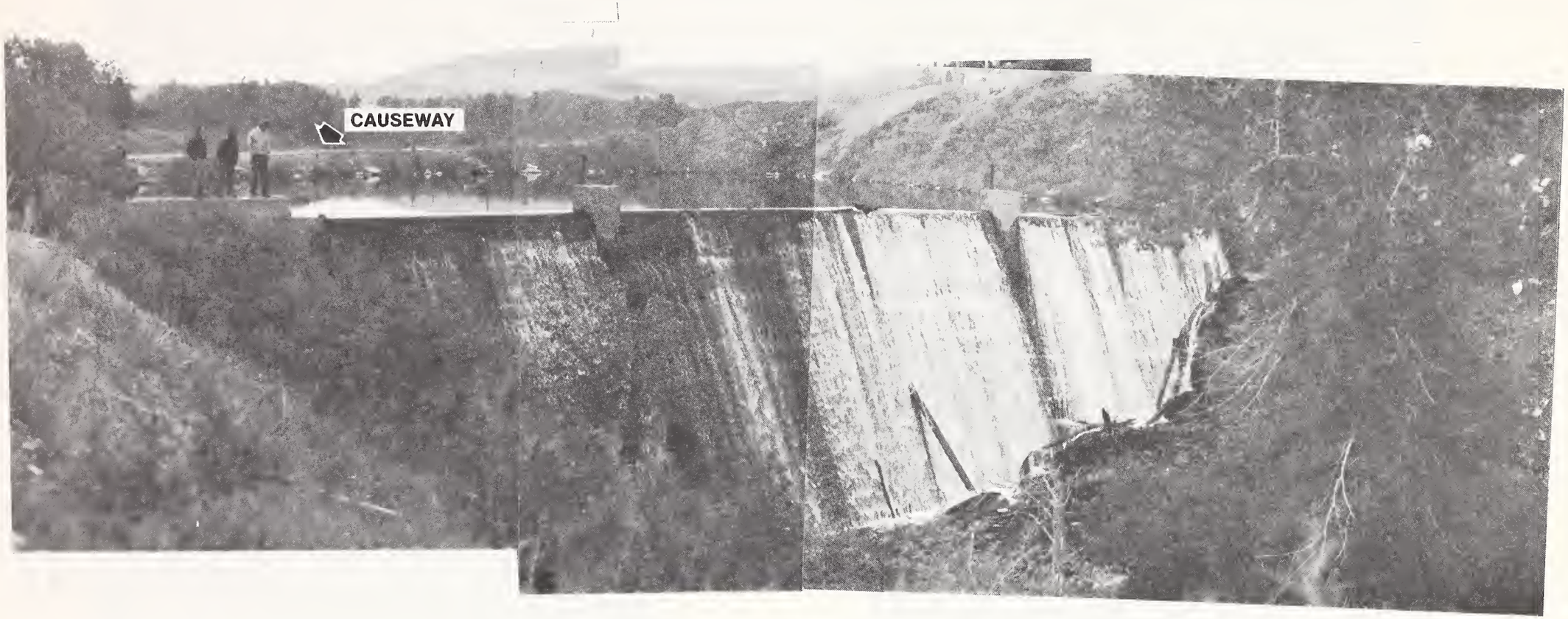


Photo 1 Northern Pacific Reservoir Dam
East Helena, Montana

INSPECTION PHOTOGRAPHS TAKEN, SEPTEMBER 20TH, 1978

Photo 2 Northern Pacific Reservoir Dam
Dam Crest

Photo 3 Northern Pacific Reservoir Dam
Dam Face

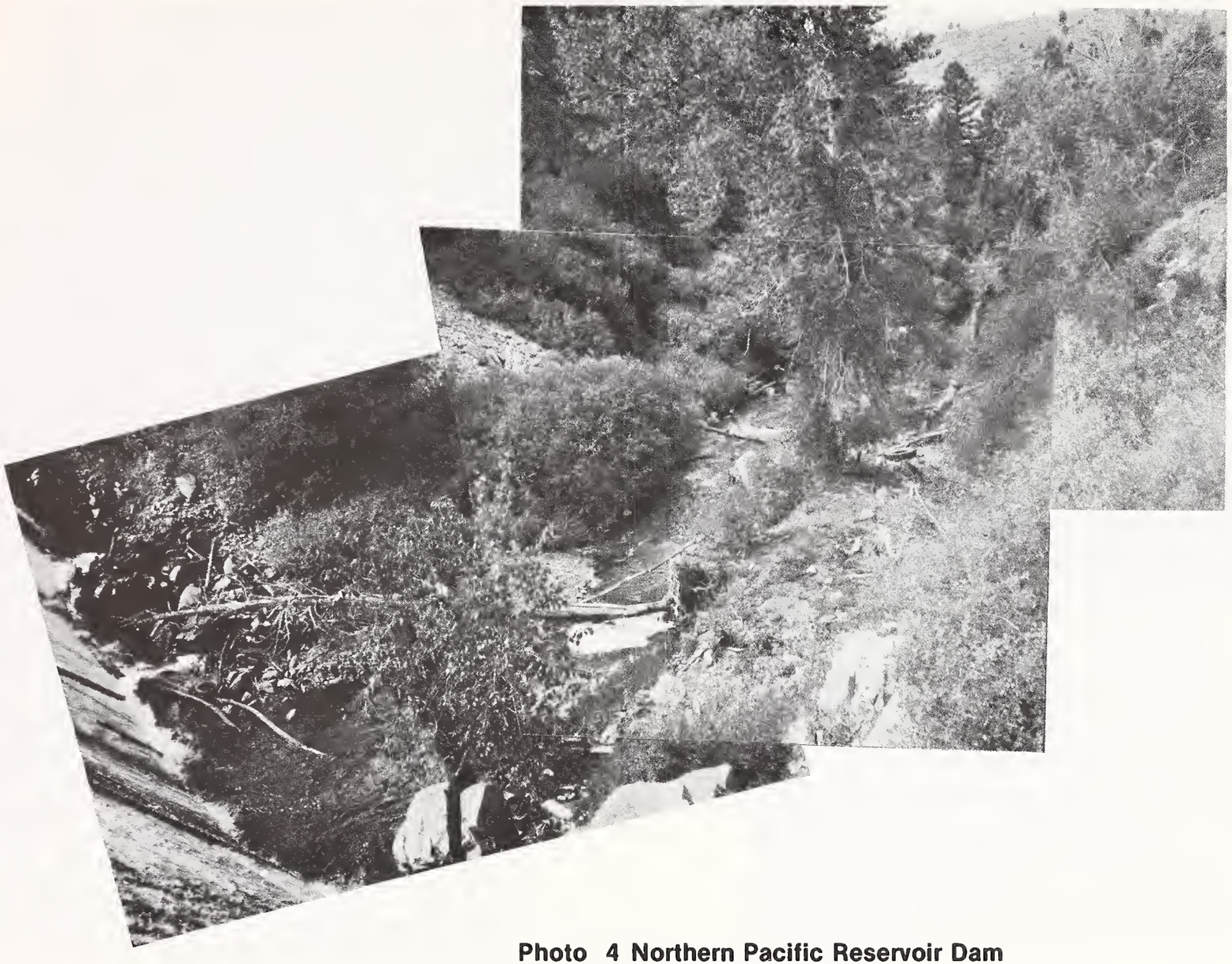


Photo 4 Northern Pacific Reservoir Dam
Downstream Channel

Photo 5 Northern Pacific Reservoir
Pool Directly Behind Dam

Photo 6 Northern Pacific Reservoir Dam
Seepage and Concrete Erosion at
Right (North) Abutment

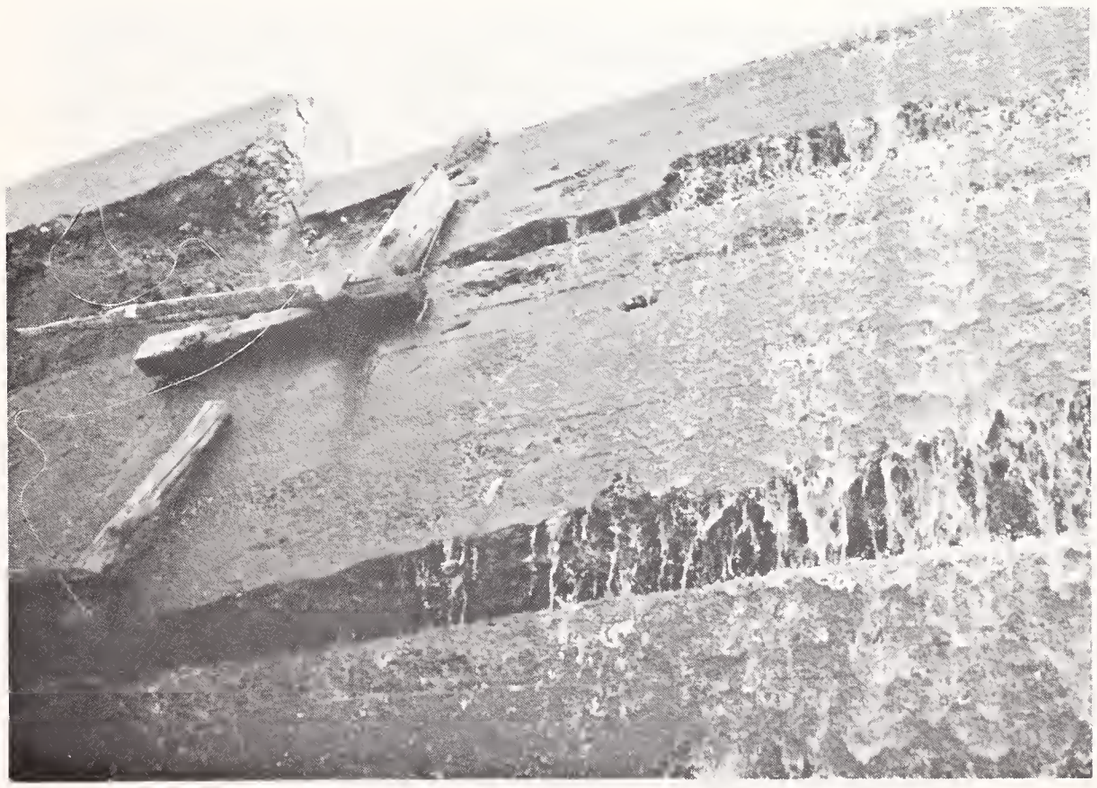


Photo 7 Northern Pacific Reservoir Dam
Concrete Erosion on Face of Dam

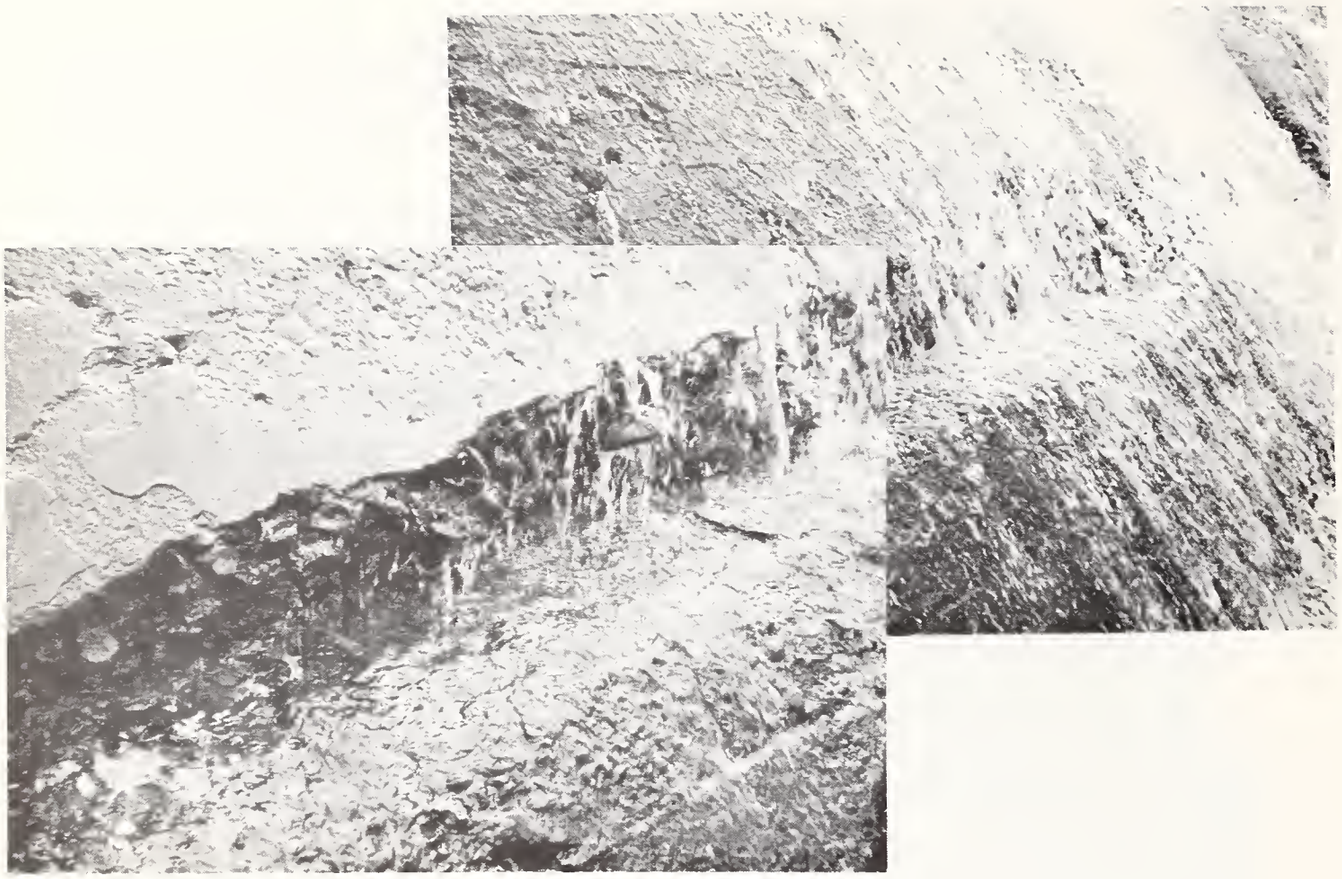


Photo 8 Northern Pacific Reservoir Dam
Concrete Erosion on Face of Dam

Photo 9 Northern Pacific Reservoir Dam
Close Up of Dam Face

Photo 10 Northern Pacific Reservoir Dam
Concrete Erosion on Dam Face and
at Piers

Photo 11 Northern Pacific Reservoir Dam
Concrete Erosion on Face and at Piers

CORRESPONDENCE

ASARCO Incorporated

EAST HELENA PLANT
EAST HELENA, MONTANA
59635

TEL. 406-227-531

P A DeSANTIS
MANAGER

R D HEARST
SUPERINTENDENT

J E ELDREDGE
ACCOUNTING MANAGER

January 17, 1980

Maxey B. Carpenter, Jr.
Lt. Colonel, Corps of Engineers
Acting District Engineer
Seattle District
P. O. Box C-3755
Seattle, WA 98124

Dear Sir:

On October 23, 1979, you transmitted to Asarco Incorporated a Draft Phase I Inspection Report entitled, "McClellen Creek Basin, Northern Pacific Reservoir Dam, East Helena, Montana, MT-858." In your cover letter, you requested Asarco's comments by November 16, 1979. Asarco requested and the Corps agreed to extend the comment period to December 16, 1979. During this time, Asarco management personnel in New York City and Salt Lake City reviewed the report and Asarco's Senior Hydrogeologist made a personal inspection of the Northern Pacific Reservoir Dam. Asarco personnel felt that the draft Inspection Report contained insufficient factual information about the dam or the downstream hazards reasonably expected if the dam should fail. Therefore, Asarco contracted with an independent engineering firm, Morrison-Maierle, Inc., to perform a downstream hazard assessment in case of dam failure and to determine the need for additional investigations of the dam and outline alternative measures.

Asarco personnel felt that this engineering study should be completed before commenting on the draft Inspection Report. Therefore, Asarco requested a second extension of the comment period to January 18, 1980, which was approved by the Corps. Asarco appreciates the cooperation of the Corps.

The engineering study of the downstream hazards associated with a dam failure has been completed. The report and support documentation are enclosed as Attachment A to these comments. The study shows that a dam failure would not result in a catastrophic flood. All inhabitable structures between the dam and the smelter are well above all flood elevations. Other key structures, such as railroad bridges, between the dam and the smelter would not be adversely affected by a dam failure. Therefore, the hazard potential for loss of life and for property destruction is minimal. The flood wave rapidly dissipates as it proceeds downstream because the Prickly Pear Creek flood plain is 2,000 to 3,000 feet wide near the smelter. Thus, the maximum rise in water surface elevation would be one foot at the smelter. However, this water rise would

result in flooding of portions of the smelter and flooding of portions of the City of East Helena, which would result in property damage. Loss of life would not be expected. Thus, the downstream hazard potential in case of dam failure would be property damage in the smelter and City of East Helena.

Nevertheless, Asarco intends that the Northern Pacific Reservoir Dam should be safe. However, more study is needed to assess the correct course of action. One study option is to investigate the structure and stability of the dam. For example, Asarco personnel believe that the dam is a modified-arch type which is more stable than the gravity type dam (assumed for the preliminary stability analysis in the draft Inspection Report). Asarco personnel feel that the dam is safer than indicated in the draft Inspection Report based on historic high water level occurrences over the last forty years.

Another option is to take corrective actions without a structural analysis of the dam. Obviously, any corrective action must have a cost-benefit study. The costs are expected to be high in relation to benefits because Asarco has no present or anticipated future use for the impounded water. Corrective actions could also result in adverse water quality impacts (such as siltation) which would require input and coordination with the State Water Quality Bureau.

In summary, Asarco wants the Northern Pacific Reservoir Dam to be safe, but more study is needed. Asarco emphasizes that the dam has been safe for over forty years, and that the downstream hazard potential for loss of life and property destruction is low, but that property damage in the smelter and City of East Helena could be expected.

Asarco requests that these comments and Attachment A be incorporated with the final Inspection Report.

Sincerely yours,

P. A. DeSANTIS

Encls.

MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS
STRUCTURAL WATER RESOURCES ENVIRONMENTAL TRANSPORTATION
ENGINEERS — EARTH SCIENTISTS — PLANNERS

January 16, 1980

Mr. P.A. DeSantis, Manager
East Helena Plant
ASARCO
East Helena, Montana 59635

RE: Northern Pacific Reservoir Dam

Dear Mr. DeSantis:

Enclosed is our report presenting the findings and recommendations concerning the downstream hazard analyses of the Northern Pacific Reservoir Dam. Incorporated with this report and transmitted herein is supplemental information and support documentation of our technical analysis which may be submitted to the Corps of Engineers with your response. These items include:

1. Attachment A - Guidelines for Emergency Preparedness Plans.
2. Attachment B - Dam Classification Guidelines
3. Aerial Map Showing Cross-section Locations
4. Flood Boundary and Floodway Map of East Helena
5. Water Surface Profiles
6. Channel Storage-outflow Curves
7. Support Computations and Computer Printours
8. Cross-section Plots.

It is the findings of our analysis that a potential downstream hazard does exist at the ASARCO plant and in East Helena. The hazard is greatest if the dam should fail under a low flow condition. This would be the condition described as the point when stability criteria is exceeded during a flow over the dam of 3 feet. If the dam failed under this condition the flow at the plant would double from 1070 cfs to 2380 cfs resulting in a one foot rise in water surface elevation. Although this is not a catastrophic flood wave condition, it would cause significant flooding and property damage over and above the 100-year flood.

It is our recommendation that ASARCO proceed with evaluating alternate corrective measures to determine the most appropriate means of rendering the project safe.

P. O. BOX 6147 | 910 HELENA AVENUE — HELENA, MONTANA 59601 — PHONE 406 442-3050
TWX 910 983 2453 CABLE — MMHELENAMT

It is further our finding that ASARCO could sustain substantial flood damage from high flows in Prickly Pear Creek. We recommend that a dike be constructed between the slag pile and the bag flue house to prevent flood waters from entering the plant area.

If you have any questions concerning our analysis or if you would like us to expand on any area of the report, please contact us. We are available to discuss our findings with you in more detail or provide you with assistance in preparing your response to the Corps of Engineers.

Sincerely,

MORRISON-MAIERLE, INC.

Rodger C. Foster, P.E.
Project Manager

RCF/smk/52/P

NORTHERN PACIFIC RESERVOIR DAM
MT-858
DOWNSTREAM HAZARD INVESTIGATION

PURPOSE AND SCOPE

The Phase I Inspection Report for the Northern Pacific Reservoir Dam (Quarry Dam) states the dam is unsafe because it does not meet minimum stability criteria and because there is a high potential downstream hazard associated with a failure of the dam. The report also recommends certain actions be taken by ASARCO to provide a more detailed stability analysis and if necessary, it recommends appropriate action be taken to make the project safe.

In order to respond to the report as requested by the Corps of Engineers, ASARCO retained the services of Morrison-Maierle, Inc., the Consultant, who conducted the Phase I Inspection, to perform the necessary more detailed analyses. The analyses were to be completed in two phases. The first phase would address in more detail the hazard associated with a dam failure. If the downstream analyses indicates no hazard exists then it would not be necessary to make major repairs to the dam. If a hazard does exist then a second phase of analysis would be necessary to address the stability of the dam and possible corrective measures.

The analysis and findings presented herein address the first phase effort. It is the purpose of the first phase analysis to:

1. Perform a downstream dam break analysis in order to access more accurately the hazards associated with the dam failure;

2. Determine the need for additional investigations of the dam and outline alternative measures;

3. To recommend guidelines for the development of an emergency preparedness plan by ASARCO.

AUTHORITY

This engineering study of the safety hazards and remedial measures for the Quarry Dam has been performed by Morrison-Maierle, Inc. under ASARCO purchase order number 5203-9 dated December 10, 1979 as authorized by Mr. P.A. DeSantis.

GENERAL APPROACH

The Phase I Inspection Report states that the dam exceeds stability criteria when a flow of approximately 1200 cfs passes over the crest of the dam at a depth of 3 feet. It further states the dam is impending failure when a flow of approximately 35,000 cfs passes over the dam at a depth of 13.5 feet. Because the reservoir has such a small volume, (approximately 150 acre-feet) if the dam failed under a high flow condition the affects of that failure in terms of flood hazard would not be as great as if it failed under a low flow condition. The downstream analysis therefore, analyzed the effects of dam failure for four flows to determine a critical failure condition. The flows analyzed represent the 1200 cfs flow, or approximately 2 percent of the Probable Maximum Flood (PMF), and flows equal to 10, 20, and 50 percent of the PMF.

The affects of the dam failure are evaluated at a point on Prickly Pear Creek immediately upstream of the ASARCO plant. At this location a haul road and small dam form a control section in the flood plain, which provides an excellent location for assessing the flooding conditions. Downstream of the plant dam, the affects of flooding are determined using the information provided in the Flood Insurance Study Report for East Helena prepared by the U.S. Geological Survey in 1979.

METHODOLOGY

Morrison-Maierle engineers performed a field reconnaissance of the flood plain area to assess general hydrologic and hydraulic characteristics and to select locations where channel cross-section data would be obtained. The enclosed aerial photo of the area shows the cross-section locations. Field data was obtained using conventional survey methods and all elevations are based on the National Geodetic Vertical Datum (NGVD).

The dam-break analysis was modeled using a steady flow procedure as outlined in the Corps of Engineers' Guidelines for Calculating and Routing a Dam-Break Flood, Research Note No. 5. This procedure uses two computer models to perform a wave analysis. The U.S. Army Corps of Engineers' program HEC-2 Water Surface Profiles is used to develop storage-outflow relationships at each cross-section location. The COE program HEC-1 Flood Hydrograph Package, Dam-Break option is then used to provide a hydrologic routing of the dam-break flood wave.

CHANNEL CONDITIONS

The McClellan Creek channel from the Northern Pacific Dam to Prickly Pear Creek has a moderately steep slope, narrow channel and high banks. Flood flows up to a PMF event would be contained within the banks and travel at very high velocities. The Highway 518 embankment crosses McClellan Creek near its confluence with Prickly Pear and was considered in place for this analysis. The highway culvert will pass approximately 1000 cfs before overtopping of the roadway will occur.

The Prickly Pear channel below McClellan Creek has a moderate slope. It begins to widen just downstream from the confluence with McClellan Creek and becomes 2000-3000 feet wide at the plant dam. Between the plant and the Highway 518 crossing there are two railroad bridges over Prickly Pear Creek at cross-sections 6 and 7 which have capacities of 5000 cfs and 6000 cfs respectively. Both bridges were considered in place for this analysis.

The west boundary of the Prickly Pear Creek flood plain is formed by a railroad embankment which extends for the entire stream reach to the plant. The grade of the railroad is high and would not be overtopped by the flood wave. The flood plain upstream of the plant dam, which is represented by cross-section 3, is broad and flat. Between cross-section 3 and cross-section 8 there is substantial channel storage available which has a dampening effect on the flood wave.

There are occasional houses between the Quarry dam and the plant and field elevations show the lowest houses to be above the affects of the flood wave.

A special condition exists at cross-section 3 which is the control section at the plant dam and haul road. Flow in a large percentage of the cross-section is blocked by the bag house flue and the plant slag pile. The flood flows at this point would be split approximately 50-50, with half going through the plant and half continuing down the Prickly Pear channel. The split flows would reunite again at the main Burlington Northern tracks.

The flood peaks between cross-section 1 and 3 would not be reduced appreciably due to the negligible routing effects of the narrow channel which has an approximate bankfull capacity of 10,000 cfs. Therefore, the flows at cross-section 3 were transferred directly to East Helena.

ANALYSIS

The Northern Pacific dam-break was modeled to completely remove the dam in a span of 10 minutes and to drain the pool to the stream invert elevation. This is considered the worst possible condition and an actual failure would probably be less dramatic due to the remains of the dam, which would probably block a portion of the stream channel.

Enclosed are 4 sets of dam-break water surface profiles describing the downstream effects of failure at different flows. All dam-breaks were modeled to occur at the hydrograph peak, which produces the greatest reservoir pool elevations. A base flow of 1000 cfs was assumed for pre-failure conditions in the stream channel. Each set of profiles illustrates the following two conditions for a particular PMF ratio; 1) routing of the inflow hydrograph without a dam-break and, 2) routing of the inflow hydrograph with a dam-break. Elevations for the lowest houses between cross-sections 3 and the N.P. Dam are also shown on the profiles.

The following table summarizes the results presented on the profile sheets.

PMF Ratio	Inflow to N.P. Res.(cfs)	Routed peak flow conditions at cross-section 3, cfs		Rise in Water Surface at Plant (Ft.)
		Without Dam-break	With Dam-break	
.02	1,300	1,070	2,380	1.0
.1	7,300	6,200	7,800	0.3
.2	14,700	13,800	18,200	0.4
.5	36,700	35,400	36,400	0.1

All of the profiles indicate that the houses located between cross-section 3 and the N. P. Dam are well above all flood elevations. The low flow failure would overtop the Highway 518 embankment approximately 1,000 feet downstream from the dam, but would pass through the two railroad bridges. Some damage to the highway embankment would be expected. The 0.1, 0.2 and 0.5 PMF events would overtop all 3 embankments without the dam failure. The failure of the dam during these events would not cause appreciably greater overtopping.

Table 1 and the profiles illustrate the decreasing downstream hazard of a dam failure at the higher flows when compared to the hazard of the higher flows alone. The greatest rise in water surface elevation would occur if the Northern Pacific Dam were to fail at the smallest inflow ratio (0.02 PMF). This failure would increase the flow at the ASARCO plant dam from 1070 to 2380 cfs and increase the water surface elevation from 3916.8 to 3917.8 feet. Approximately one-half of the 2380 cfs would flow over the ASARCO haul road and into the plant facilities. It should be noted that the travel time for the flood wave to reach the ASARCO plant is approximately one hour. Therefore, if the Northern Pacific Dam were to fail there would not be enough time to construct a dike to protect the plant buildings.

The highest hazard in the City of East Helena associated with the dam failure would be from the low flow failure at an inflow of 1300 cfs. This failure would produce a peak flow of 2380 cfs through the City of East Helena. The effects of this flow can be estimated using the flood insurance study for East Helena (see the enclosed profiles and delineations). The hydrology used for that flood study indicates the 100-year and 500-year flood respectively as 1270 and 1770 cfs. Therefore, while the pre-failure

flow of 1300 cfs at the dam represents approximately a 100-year event at East Helena, the dam-break flood peak of 2388 cfs would create flooding problems greater than the 500-year flood delineation presented on the flood insurance map. Most of this flooding would be shallow and probably not cause any loss of life. However, property damage would be extensive and result in large dollar losses. Property damage from the 0.1, 0.2 and 0.5 PMF ratios would be extensive and probably would not increase appreciably due to the failure of the Northern Pacific Dam.

CONCLUSIONS AND RECOMMENDATIONS

The dam-break analysis indicates that a failure of the dam during low flow conditions would produce the greatest affect downstream at the ASARCO Plant and in East Helena. Although there would be no catastrophic flood wave, a dam failure would cause flood damage in excess of what would be expected without a failure. A failure at a flow of 1300 cfs would cause the water surface to rise approximately one foot above the 100-year flood elevation at the plant and in East Helena.

It is concluded that a hazard does exist downstream for flow conditions less than a 10 percent PMF. At that flow and higher flows, the effects of a failure are considered negligible. It is therefore recommended that:

1. A phase two analysis will be performed to evaluate alternate corrective measures at the dam;

2. The hazard classification of the dam be reduced from high to significant, which would reduce the spillway design flood requirement to a range between a 100-year flood and ½ PMF;

3. The spillway design flood be set at 10 percent of a PMF.

One additional recommendation is made with regard to protecting the ASARCO Plant from large floods. As described in this report, a low area in the haulroad and dike immediately upstream of the plant allows approximately one half of the flood flows to enter the plant area. To protect the plant it is recommended that a dike be constructed at a minimum elevation

of 3920 feet (NGVD) and tied into the slag pile and to the bag-house flue. This action would protect the plant and cause flood flows to be diverted to the main channel at the plant dam.

ALTERNATE CORRECTIVE MEASURES

Due to the potential hazard downstream, alternate corrective measures need to be addressed which will bring the dam into compliance with dam safety guidelines. Following is a list of measures which could be considered with a short discussion of what each would involve.

1. Removal of Dam - This would eliminate the hazard but could present environmental problems associated with releasing trapped sediment. The cost of this alternative would be expected to be substantial.

2. Stabilizing the Dam - Alternatives for stabilizing the structure could be investigated such as anchoring it or supporting it with buttresses on the downstream face. This measure would require a full stability analysis and engineering design in addition to the repair work. The cost of this alternative would be expected to be high.

3. Lower the Dam - If the top ten feet of the dam were removed and the storage reduced to 50 A.F., the dam would fall below the minimum criteria of the dam safety program. It could then presumably be eliminated from further consideration. This alternative would require field investigations to determine the stability of the dam and its structural integrity. The cost of this alternative would be expected to be high.

4. Detailed Stability Analysis - A detailed stability analysis of the existing structure could be performed to determine more accurately what flow conditions the dam can safely withstand. If it can withstand 10 percent of a PMF no additional work may be required. The analysis would require foundation exploration and coring of the dam. This alternative would be less costly than the previous alternatives and would be a prerequisite to all but the removal alternative.

5. Increase Outflow Capacity - If the dam is stable under low flows, it might be possible to increase the flow for which the dam is stable by grading the overbank area to allow increased flow at a lower head.

6. Reduce the Storage Capacity of the Reservoir - By reducing the storage capacity of the reservoir the volume released during a failure would be reduced and the downstream effect would be less. The reservoir between the dam and the causeway could be filled with rock to achieve the reduction in volume. This alternative would require a stability analysis and additional hydraulic analyses.

GUIDELINES FOR EMERGENCY REPAREDNESS PLAN

A. Development of the Emergency Preparedness Plan

1. An Emergency Preparedness Plan (EPP) is required for the Northern Pacific Dam due to the downstream hazard that would be associated with its failure.

2. The EPP should be discussed with the East Helena community leaders and officials during its development so that those persons directly responsible for the well-being of the citizenry have an opportunity to provide input. The EPP should include a warning system for the downstream hazard areas. Local officials should be made clearly aware of the significance of the dam-break hazard and ASARCO personnel should work closely with them to develop communication, warning and evacuation procedures.

3. Heads of other Federal, State and County agencies which may be affected should be informed and consulted with.

B. Minimum Requirements of the EPP

1. The emergency situation at the dam that would require notification of local officials should be clearly defined. During heavy runoff periods it should be the responsibility of one or more persons to periodically check the dam site and issue the first warning of a potentially hazardous situation (one reaching emergency status).

2. This warning should follow down a chain of command laid out in a directory that includes the names; addresses and telephone numbers of key ASARCO, East Helena and Lewis and Clark County officials.

3. The primary communications system should be clearly identified and tested. Alternate methods of communication should be outlined

in the event of a primary system failure. All systems should contain complete instructions for their use and maintenance.

4. Inundation maps of areas expected to be flooded in the event of a dam failure should be prepared and distributed. The maps should include zones of warning priority.

5. The EPP should contain the location of the most readily available heavy construction equipment, materials (soil, rock, plastic sheeting, sand bagging, etc.) labor, and engineering expertise to be used in the event of a dam failure. A plan should be prepared to use this equipment and manpower to minimize flood damages to the ASARCO plant and East Helena.

6. Provisions should be made for the periodic review of the EPP for the purpose of training new personnel and updating the EPP due to new developments. This review procedure should include the local community leaders in order to maintain coordination and understanding.

SAFETY CLASSIFICATION OF DAMS

EXCERPTED FROM: Recommended Guidelines for Safety Inspection of Dams

2.1 Classification of Dams. Dams should be classified in accordance with size and hazard potential in order to formulate a priority basis for selecting dams to be included in the inspection program and also to provide compatibility between guideline requirements and involved risks. When possible the initial classifications should be based upon information listed in the National Inventory of Dams with respect to size, impoundment capacity and hazard potential. It may be necessary to reclassify dams when additional information becomes available.

2.1.1 Size. The classification for size based on the height of the dam and storage capacity should be in accordance with Table 1. The height of the dam is established with respect to the maximum storage potential measured from the natural bed of the stream or watercourse at the downstream toe of the barrier, or if it is not across a stream or watercourse, the height from the lowest elevation of the outside limit of the barrier, to the maximum water storage elevation. For the purpose of determining project size, the maximum storage elevation may be considered equal to the top of dam elevation. Size classification may be determined by either storage or height, whichever gives the larger size category.

TABLE 1
SIZE CLASSIFICATION

Category	Impoundment Storage (Ac-Ft)	Impoundment Height (Ft)
Small	< 1,000 and > 50	< 40 and > 25
Intermediate	> 1,000 and < 50,000	> 40 and < 100
Large	> 50,000	> 100

2.1.2 Hazard Potential. The classification for potential hazards should be in accordance with Table 2. The hazards pertain to potential

loss of human life or property damage in the area downstream of the dam in event of failure or misoperation of the dam or appurtenant facilities. Dams conforming to criteria for the low hazard potential category generally will be located in rural or agricultural areas where failure may damage farm buildings, limited agricultural land, or township and country roads. Significnt hazard potential category structures will be those located in predominantly rural or agricultural areas where failure may damage isolated homes, secondary highways or minor railroads.

HAZARD POTENTIAL CLASSIFICATION

CATEGORY	LOSS OF LIFE (Extent of Development)	ECONOMIC LOSS
Low (Hazard = 3)	None expected (No permanent structures for human habitation)	Minimal (Farm buildings, limited agricultural, land or county roads)
Significant (Hazard = 2)	Few (No urban development and no more than 2 inhabitable structures)*	Appreciable (Notable agricultural, secondary highways, minor railroads or cause interruption of use or service of relatively important public utilities)
High (Hazard = 1)	More than a few (greater than 2 inhabitable structures)*	Excessive (Extensive community, industry or agriculture including important public utilities, main highways or railroads)

*inhabitable structures within flood path caused by dam break.

The spillway design flood is determined from Table 3 using the hazard and size classificaton assigned to the structure.

HYDROLOGIC EVALUATON GUIDELINES
RECOMMENDED SPILLWAY DESIGN FLOODS

Hazard	Size	Spillway Design Flood (SDF)
Low	Small	50 to 100-yr freq
	Intermediate	100-yr to 1/2 PMF
	Large	1/2 PMF to PMF
Significant	Small	100-yr to 1/2 PMF
	Intermediate	1/2 PMF to PMF
	Large	PMF
High	Small	1/2 PMF to PMF
	Intermediate	PMF
	Large	PMF

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872

HELENA, MONTANA 59601

December 28, 1979

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on the American Smelting and Refining Company Northern Pacific (NP) Reservoir Dam near East Helena. We comply with the findings and recommendations and feel the report is complete and satisfies the criteria for the Phase I evaluation. Minor editorial comments have been discussed with your staff and we understand these will be included in the final report.

Thank you for this opportunity to review and comment on the final draft report for this project.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB:GM:mb

MORRISON-MAIERLE, INC.
QUALITY ASSURANCE

Project Manager

Branch Manager or Department Head

Peer Reviewer

Harold L. Eagle
Principal-In-Charge

Chief Engineer No.	Date Approved
80-08	10 APRIL 80

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